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Experimental Investigation and Optimization of Effect of Fly Ash Addition into AL 7075 Metal Matrix Composite

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ABSTRACT

The present study investigates the experimental development, characterization, and optimization of aluminum 7075 (Al 7075) metal matrix composites (MMCs) reinforced with varying proportions of fly ash. Fly ash, a lightweight industrial byproduct, was incorporated as a particulate reinforcement to enhance the mechanical and tribological properties of Al 7075. Composites were fabricated using the stir casting method, ensuring uniform distribution of fly ash particles within the matrix. The influence of fly ash content on density, hardness, tensile strength, wear resistance, and microstructural behavior was systematically analyzed. Experimental results revealed that the addition of fly ash significantly improved hardness and wear resistance, while a slight reduction in tensile strength was observed at higher reinforcement levels. Optimization of fly ash content was carried out to achieve a balance between mechanical strength and wear performance, indicating an optimum reinforcement level for superior composite performance. Microstructural analysis confirmed homogeneous particle dispersion and strong interfacial bonding between the Al 7075 matrix and fly ash particles. The findings highlight the potential of fly ash-reinforced Al 7075 composites as lightweight, cost-effective, and high- performance materials for automotive, aerospace, and structural applications.

Keywords: Al 7075, Metal Matrix Composite, Fly Ash, Stir Casting, Mechanical Properties, Wear Resistance, Microstructure, Optimization.

1. INTRODUCTION

Aluminum alloys, particularly **Al 7075**, are widely used in aerospace, automotive, and structural applications due to their high strength-to-weight ratio, excellent corrosion resistance, and good fatigue properties. However, conventional aluminum alloys often face limitations in wear resistance and hardness when subjected to extreme operating conditions. To overcome these limitations, **metal matrix composites (MMCs)** have emerged as a promising solution, where a metal matrix is reinforced with particles, fibers, or whiskers to improve mechanical and tribological properties. **Fly ash**, an industrial byproduct of coal combustion, has gained attention as a cost-effective and lightweight particulate reinforcement for MMCs. Incorporating fly ash into aluminum matrices can enhance hardness, wear resistance, and stiffness while reducing the overall weight and production cost of the composite. Additionally, using fly ash supports sustainable manufacturing by recycling industrial waste.

Several fabrication techniques, such as stir casting, powder metallurgy, and squeeze casting, have been employed to produce aluminum-fly ash composites, with **stir casting** being preferred for its simplicity, uniform particle distribution, and scalability. This study focuses on

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the **experimental investigation of Al 7075 reinforced with varying fly ash content**, analyzing mechanical properties, wear behavior, and microstructural characteristics, and optimizing reinforcement levels to achieve superior performance.

Problem Statement

Although **Al 7075 alloy** exhibits excellent strength and corrosion resistance, its relatively low hardness and poor wear resistance limit its application in high-friction and high-load environments such as automotive and aerospace components. Conventional strengthening methods, like heat treatment, improve strength but often fail to provide significant wear resistance. The challenge lies in developing a **lightweight, cost- effective, and high-performance composite material** that enhances both the mechanical and tribological properties of Al 7075 without significantly increasing weight or production cost. While fly ash, an industrial waste material, has potential as a reinforcing agent, there is limited systematic investigation on its optimal content and effect on the mechanical, wear, and microstructural properties of Al 7075 composites.

This research aims to **experimentally investigate and optimize the addition of fly ash into Al 7075 metal matrix composites** to address the limitations of conventional aluminum alloys and promote sustainable use of industrial byproducts.

Objective

The primary aim of this study is to develop and optimize fly ash-reinforced Al 7075 metal matrix composites to enhance their mechanical and tribological performance. The specific objectives are:

1. To fabricate Al 7075 composites with varying percentages of fly ash using the stir casting technique.
2. To investigate the effect of fly ash addition on key mechanical properties such as hardness, tensile strength, and impact resistance.
3. To analyze the wear behavior of the composites under different load and sliding conditions.
4. To examine the microstructure of the composites to assess particle distribution, bonding, and potential defects.
5. To determine the optimal fly ash content that provides a balance between mechanical strength, wear resistance, and material cost.

2. DESIGN METHODOLOGY

The research methodology for developing and optimizing Al 7075 metal matrix composites reinforced with fly ash is designed to systematically investigate the effect of reinforcement on mechanical and tribological properties.

The approach combines experimental fabrication, testing, and optimization.

Material Selection

- Matrix Material: Al 7075 alloy, chosen for its high strength, corrosion resistance, and widespread industrial applications.
- Reinforcement: Fly ash particles, selected for their low density, hardness, and cost-effectiveness as an industrial byproduct.

Composite Fabrication:

- The stir casting method is employed to fabricate composites, ensuring uniform dispersion of fly ash particles in the molten Al 7075 matrix.
- Fly ash is added in varying weight percentages (e.g., 0%, 5%, 10%, 15%) to study its effect

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on properties.
- Proper preheating of fly ash and degassing of the melt are performed to minimize porosity and improve bonding.

Sample Preparation
- Cast composites are machined into standard specimens for mechanical testing (tensile, hardness, impact) and wear evaluation.
- Surfaces are polished for microstructural analysis.

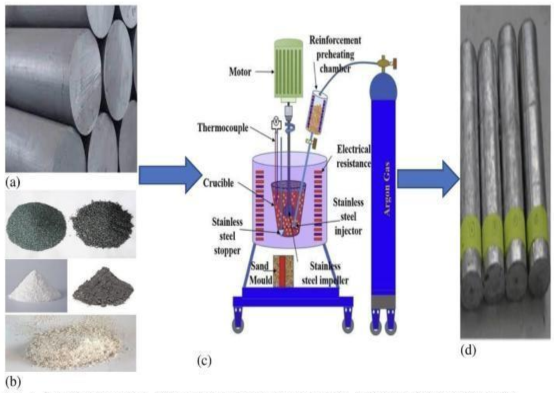

Fig. 1. (a) Al-7075 Alloy, (b) Particulate Reinforcements, (c) Stir Casting Setup with sand mold and (d) Casted Specimens

Experimental Testing
- Mechanical Tests: Hardness (Rockwell/Brinell), tensile strength, and impact strength are measured.
- Wear Tests: Pin-on-disc or block-on-ring methods are used to evaluate wear resistance under varying load and sliding conditions.

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Testing rod

Optimization

- Experimental results are analyzed to determine the optimal fly ash content that achieves a balance between hardness, strength, and wear resistance.
- Statistical tools or design of experiments (DOE) can be applied for precise optimization.

Data Analysis and Interpretation

- Mechanical and wear test results are compared across different fly ash percentages.
- Microstructural observations are correlated with performance metrics to explain material behavior.

This methodology ensures a systematic evaluation of fly ash reinforcement in Al 7075, providing insights into fabrication, property enhancement, and optimal composite design for industrial applications.

3. CONCLUSION

Incorporating fly ash into Al 7075 significantly improves hardness and wear resistance, while tensile strength slightly decreases at higher reinforcement levels. Microstructural analysis shows uniform particle distribution and strong bonding. An optimum fly ash content provides a balance between mechanical and tribological performance. Fly ash- reinforced Al 7075 composites offer a lightweight, cost-effective, and sustainable material suitable for aerospace, automotive, and structural applications.

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